

Supplemental Material

Experimental implementation of a joint statistical image reconstruction method for proton stopping power mapping from dual-energy CT data

S1. Residual I -value modeling error for reference human tissues

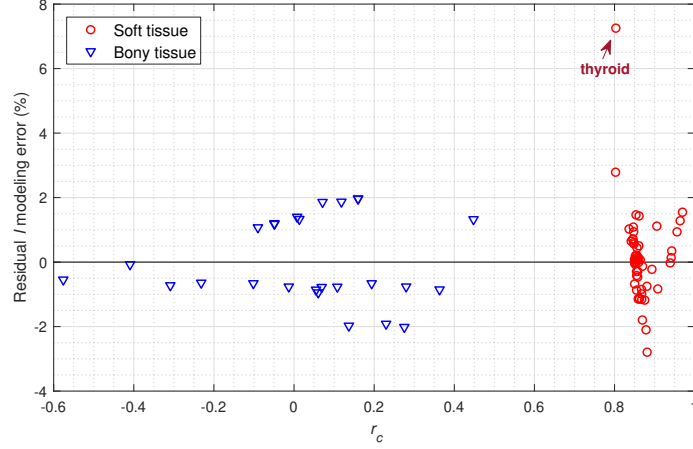


FIG. S1. The residual modeling errors for each individual reference human tissue compositions via the parameterization model shown in Figure 1. The soft tissues and bony tissues use the separate fittings.

S2. Theoretical modeling error for phantom materials

TABLE S1. Residual modeling errors of electron densities, mean excitation energies, and proton SPRs for the phantom materials.

Material	JSIR-BVM			Image HS		
	ρ_e (%)	I (%)	SPR (%)	ρ_e (%)	I (%)	SPR (%)
Water	0.12	0.42	0.07	0.00	-0.09	0.01
Acetone	0.02	-3.38	0.42	-0.11	-2.42	0.17
Ethanol	0.00	2.18	-0.25	-0.13	3.26	-0.50
n-Propanol	-0.02	2.43	-0.29	-0.15	3.30	-0.52
n-Butanol	-0.03	2.59	-0.32	-0.16	3.24	-0.53
CaCl-1	0.09	0.86	-0.02	0.00	2.31	-0.28
CaCl-2	0.03	2.69	-0.29	-0.02	3.36	-0.42
CaCl-3	0.00	3.52	-0.42	-0.02	2.76	-0.35
KP-1	0.10	-0.87	0.20	0.00	0.26	-0.03
KP-2	0.08	-1.36	0.25	0.00	0.29	-0.03
KP-3	0.05	-2.13	0.31	0.00	-1.44	0.18
KP-4	0.01	-3.16	0.40	0.00	-5.62	0.71

S3. Spatial resolution of the reconstructed SPR image

To quantify the spatial resolution of the SPR images reconstructed by the two investigated methods, we followed the analysis of Evans *et al.* (MedPhys 82(3):1444, 2011) to determine the modulation transfer function (MTF) by fitting the edge-spread function (ESF) of the insert-background edges. The pixels around the circular insert are sampled to form a super-sampled edge-spread function and then used to fit a parametric ESF model defined as

$$\text{ESF}(r) = d \cdot \left\{ a \cdot (1 - \exp(-b \cdot |r|)) + (1 - a) \cdot \text{erf}(c \cdot |r|) \right\} + e, \quad (1)$$

where $a-e$ are fitting parameters. The ESF was differentiated to get the line-spread function (LSF) and the MTF was computed as the Fourier transform (FT) of the LSF, i.e.,

$$\text{MTF}(f) = \left| \mathcal{FT} \left\{ \text{LSF}(r) \right\} \right| = \left| \mathcal{FT} \left\{ \frac{d}{dr} \text{ESF}(r) \right\} \right|. \quad (2)$$

More detail of the procedure can be found in the original work by Evans *et al.*

Because the MTF of the SPR image may be contrast-dependent, we selected three inserts in the head phantom with different contrasts for this analysis. Figure S2 compares the MTFs for both methods. The image-HS method, which utilizes the scanner's reconstructed CT images, shows similar resolutions for the three inserts, while the JSIR-BVM method achieves higher resolution for bone-like materials. The JSIR-BVM method also achieves higher resolution for each individual insert than the image-HS method.

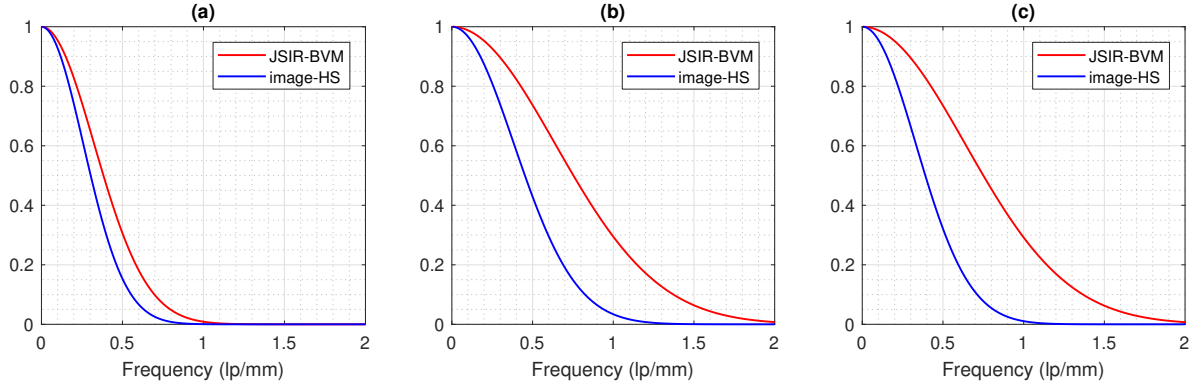


FIG. S2. The calculated MTF of the two investigated methods for (a) n-Butanol (SPR = 0.848), (b) KP-1 (SPR = 1.058), and (c) KP-4 (SPR = 1.346).